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ABSTRACT

A history of geology and geography and a brief discussion of many processes which change the face of the earth are detailed in this booklet. The discussion considers time, space, and spirit. Time refers to a sense of history; space refers to geography; and spirit refers to life and thought. Several chapters related to the concepts of geology and geography, a time line on the concepts, a map of the important geography related to the concepts, a glossary of important terms, and a list of several study suggetions are included. (CW)

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The Changing Earth

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A HAWKHILL LEARNING POWER BOOK

2

TIME, SPACE AND SPIRIT

KEYS TO SCIENTIFIC LITERACY

To the student,

This short book will help you understand our modern world. It has changed a lot since your parents were born. Even more since you were born. And it will change still more–much more–in your lifetime.

What is behind most of these big changes? Two things. Science and technology.

What can you do about it? The first step is to understand more about science and technology and how they connect with our world. Especially the ever-growing world of free democratic societies. One way to do this–the way this book follows–is to look at the world from three angles: *Time, Space* and *Spirit*.

Time means history. You can learn how science and technology have worked in the past and are working today.

Space means geography. You can learn where important things happened in the past and are happening today.

Spirit means life. The life of the mind. You can learn the key words, concepts and ideas that power science and technology (and society) today.

This book teaches about science, technology and society from all three of these angles–*Time, Space* and *Spirit*.

Read on.

This book belongs to:

The Changing Earth

Bill Stonebarger
Illustrations by Lin Haley

Hawkhill Associates
Madison, Wisconsin

This book is one of a series of sixteen Learning Power Books in the *Time, Space and Spirit–Keys to Scientific Literacy* series. It is designed to accompany the video program of the same name.

The *Time, Space and Spirit–Keys to Scientific Literacy* series was written and produced with consultation from the History of Science Department at the University of Wisconsin-Madison.

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beginnings of geology

In the highlands of Scotland, about 200 years ago, a studious Scotsman named James Hutton became the first man in the world to understand how rocks were made. In so doing he founded, almost singlehandedly, the modern science of geology.

beginnings of geography

Over three thousand years before James Hutton, on the eastern shores of the Mediterranean Sea, unknown sailors, merchants and soldiers, were venturing into strange lands. Lands for which they had no maps or guidebooks. They had to make the maps and guidebooks. In so doing, they founded the science of geography.

days of the cave people

Geography is the older of the two sciences. Some would say it began with our cave people ancestors. The people who lived, for instance, in southern France and painted pictures of bison and deer and wolves on walls of caves. These early people could not travel long distances, but they did trav-

el in their own neighborhood and they needed directions. Like us, they wanted to know of the dangers and the delights of places nearby and far off.

did they draw maps?

We have no records of maps they made, though it seems likely that a people who could draw this well could also draw a picture in the clay or sand to direct a fellow to the spot where the bison were last seen. Or to warn him of a tribe that was unfriendly.

travel on land difficult

Until very recent times travel on land has been a slow business. As a result maps of, and knowledge of, mountains, jungles, plains and deserts have lagged behind knowledge of coastal regions where ships could dock. People living away from the oceans could know, at best, a few square miles around their home.

importance of sailing ships

Once the sailing ship came into use, more accurate maps and more precise knowledge of the earth's surface also came into being. At least those parts near the water, especially those lands that bordered the Mediterranean Sea. For it was here on these shores that the early Phoenician sailors, and then the Egyptians, the Greeks and the Roman sailors learned more about the earth's surface and more about the variety of human beings who lived on and changed that surface.

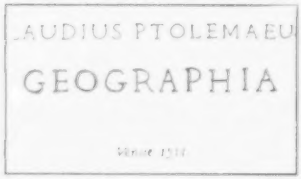
7

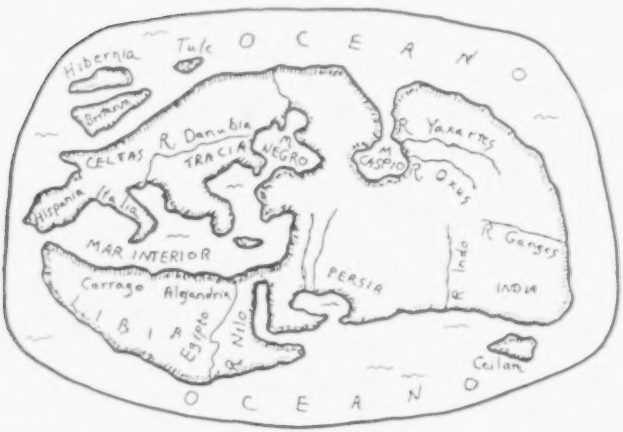
sailors from Ionian Greece

Sailors from Ionian Greece were the first to venture into the Atlantic Ocean. Trading routes were extended all the way to the British Isles and Iceland in the west, and to India and China in the east.

Ptolemy's maps and atlas

Sailors and ship owners gradually drew accurate maps of the coastal areas where their traders landed. And scholars like Ptolemy in Egypt put together the best of these maps to make some of the first world atlases. Ptolemy's atlas was the world standard for the next thousand years. It was only improved upon in the great period of scientific, artistic and geographical expansion known as the Renaissance.





the unknown earth

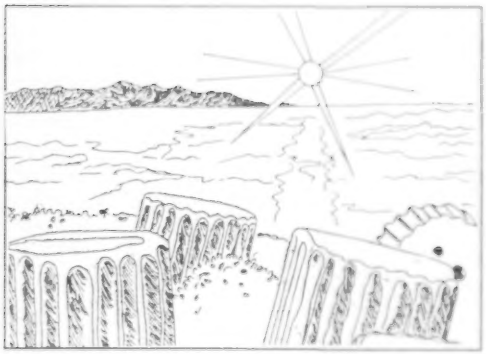
During all these years very little was known about the earth's crust, about what later was called the science of geology. There was some mining in early civilizations on all continents of the earth. But with no ways to ventilate deep shafts, and no tools to cut through hard rock, hu-

mans barely scratched the surface of the earth they walked upon or the ocean they sailed upon.

Most commonly people believed that the earth was the way it was because it had been created that way by the gods. They believed that unusual happenings like floods, earthquakes, volcanic eruptions and violent storms were sent by the gods to warn or punish human beings.

world's first scientists

On the eastern shore of the Mediterranean, in what was called Ionian Greece (now a part of modern Turkey) a group of small cities arose around 600 B.C. Cities that somehow were able to escape from the blinders of custom and taboo. Brave new thinkers challenged for the first time the magical and supernatural theories about the earth and the heavens.



Thales, generally considered the world's first natural scientist, said the earth was a disc that floated in a cosmic sea of water. Anaximander said the earth was a cylinder that revolved in the eternal heavens, with no beginning and no end. He speculated that living things, including human beings, had evolved out of the earth's water.

not much evidence

None of these early scientists had much evidence for his theories. Experimental science had to wait another two thousand years before it could be born. But these brave thinkers did help lay essential foundations for the scientific study of the earth in later centuries.

need to explore the surface of earth

Before serious study of the how, the why and the when of the earth could happen, humans had to learn the what and the where. That is, they had to explore the surface of the earth. To find the mountains, the jungles, the deserts, the rivers and the plains. And they had to communicate to other humans what they found. And then they had to put it all down on maps that others could read.

ages of exploration

So many great and brave humans played exciting parts in this search that to mention a few would risk insulting those left off the list. In tiny ships, in birchbark canoes, on horseback, camelback, muleback and on foot, men sought out the far corners of the earth. Sometimes in search of treasure, sometimes in search of souls. Often for the sheer challenge of it, and sometimes for knowledge, for science. Or all of these put together.

progress in the Renaissance

Slowly knowledge of the earth's surface and earth's peoples grew. All through historic times there was progress, but the biggest leap forward happened in the late Middle Ages and then the Renaissance. Then, for the first time, humans traveled completely around the globe. And maps and atlases grew apace.

more than maps

These maps and atlases were not only concerned with the physical surface of the earth but, just as important, they summarized our growing knowledge of the human political, economic, religious and social activities in much of their intriguing complexity. These fascinating mysteries and insights still today make up what we call geography.

how old is earth?

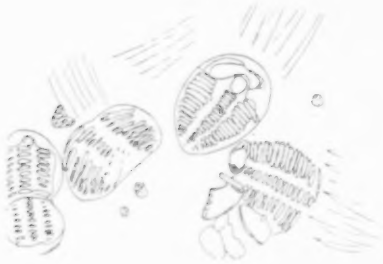
Geology, the science of the earth's construction and history, could boast of no such steady advance. Up until two hundred years ago the most common view was that the earth had been created some six thousand years ago. And created in pretty much the same state it could be seen in today. True, some scholars and scientists argued for a good deal older earth, but even an advanced eighteenth century thinker like the Frenchman Georges Buffon thought the earth was only about a hundred thousand years old, give or take a few thousand years.

fossils not understood

Fossils had been known for many centuries but until the nineteenth century they had been looked on either as freaks of nature, or as sent by the devil to tempt and to trick sinful humans.

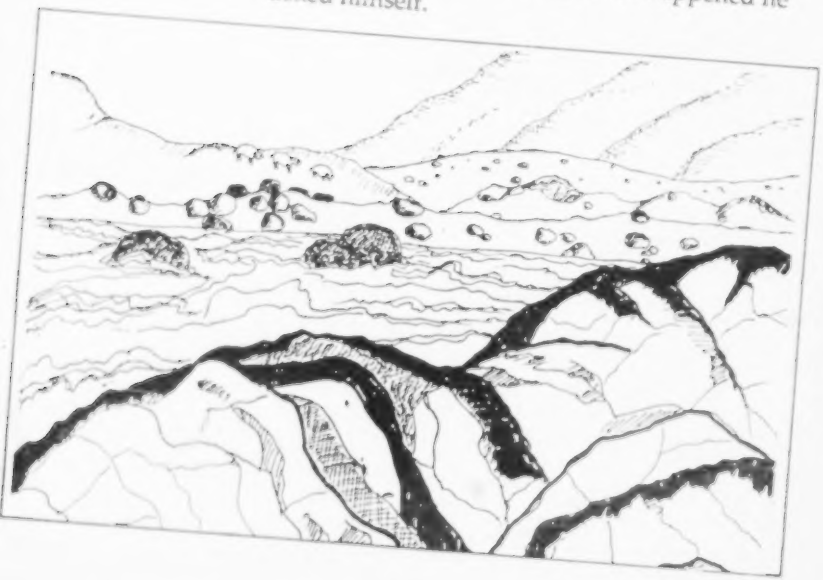
in past catastrophes?

James Hutton went into the mountains of Scotland in the late 1700s (about the time of our American Revolution). He was seeking evidence to support his revolutionary theories about the changing earth. The most accepted view at the time was that fossils, as well as all unusual mineral and rock formations, could be explained as the result of a few large catastrophes in the recent past. Especially the Biblical flood.



Hutton goes walking

One bright sunny day Hutton was exploring the rocks along a stream bed in central Scotland when he caught sight of some boulders. What especially caught his eye was the way one kind of rock, an igneous type (known to be created by great heat), had infiltrated into a totally different kind of rock, a sedimentary type (known to be created by water deposition). How could that have happened he asked himself.



millions of years of earth history

And he answered–in only one way. Not by flood, or deposition at all, but rather there must have been deep flowing changes in the rocks. There must have been cracks and molten rock invading those cracks. And all this must have taken a long long time. Not thousands, but millions of years.

the changing earth

In other words, instead of thinking of the earth as a solid stable thing, Hutton began to look on the earth as a plastic changeable thing. Albeit the changes were usually very slow. This view of the earth is the one that eventually triumphed and is held by all serious students of geology today.

Following Hutton, other geologists began to discover and to add to the picture he outlined.

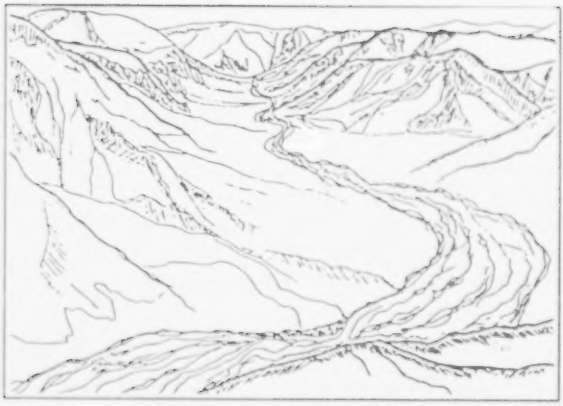
Agassiz and glaciers

Probably the most shocking discovery came in the nineteenth century and was made by Louis Agassiz. Agassiz noticed certain peculiarities in the rock formations in Switzerland. Large boulders, for instance, that were plainly made of a completely different kind of mineral than the rocks upon which they were resting. How did these giant boulders get there he asked.

He noticed gravel and sand that was sitting on underlying rock that, once again, was made of totally different minerals. How did the sand and gravel get there?

carried by ice

The startling answer Agassiz gave was that they were carried there by ice. Water, even the most powerful torrents, could not do the job. It must have been ice, ice in the form of gigantic glaciers.



continental glaciers

As he looked at other places in northern Europe and then in North America he saw more evidence as plain as the nose on your face. Giant glaciers had once covered almost the entire area of northern Europe and North America.

the evidence

You could see for yourself the evidence. Everywhere. Outwash plains, drumlins, glacial lakes where the drainage had been disrupted. You could trace the source of rocks and gravel and sand from where they are today to where they came from when the glacier picked them up in its icy fingers and then dropped them off when at last it melted. Often hundreds or even thousands of miles away!

Other lines of evidence pointed in the same direction. For at least the past two million years earth has been subject to a series of ice ages. And today we live in one of the rather short, as geological time goes, inter-glacial periods. Tomorrow (like ten or twenty thousand years from now) another ice age is slated to return.

earth much older than thought

But the revelation of ice ages over the past two million years was as nothing compared to the evidence other scientists were gathering from the fossil record, from new rock dating techniques,

and from magnetic evidence. Evidence that showed the earth to be not a few million, but a few billion years old!

And this evidence showed conclusively that not only was the earth much older than anyone had ever imagined, it had also changed more radically in all its parts over that long period.

a new theory of continental drift

A German astronomer turned geologist, Alfred Wegener, is the one generally given credit as the father of the theory called "continental drift." (Today usually called "plate tectonics")

Pangaea

Wegener proved that the continents as we know them have not always been where they are today. About five hundred million years ago they were all part of one gigantic supercontinent called Pangaea. This supercontinent was in the southern hemisphere.

tectonic plates

Continents as well as the sea floors are riding on top of very large plates of rock. These huge plates are in turn floating on top of the underlying molten rock. Very slowly these plates (and the continents riding on top of them) have been moving and separating. Since the plates are continu-

ally slipping and grinding against one another, you get a lot of earthquake and volcanic activity at the boundary lines.

at the surface in Iceland

Most of the boundary lines of the plates are under the ocean. But in a few places like Iceland, the plates collide on land. And all over that small island you can see today the steam and the lava continually breaking through the surface rock.

now accepted as fact

When this theory of plate tectonics–continental drift–was first proposed, many dismissed it as incredible. However, in recent years new discoveries have convinced most geologists that continental drift is a fact.

tasks for the future

Today geographers and geologists have a double task. Not only to sort out and make sense of the earth's surface in all its human modified complexity, but also to figure out what its surface and interior was like for centuries, for millenia, for eons of time in the past.

In Part 2 of this book we take a look at the present day picture of our changing earth.

earth, sun and me

"The green earth tilts through a sphere of air
And bathes in a flame of space.
There are houses hanging above the stars
And stars hung under a sea ...
And a sun far off in a shell of silence
Dapples my walls for me ..."

poets and scientists

How strange it is. The most common ordinary things, that is. Like the earth beneath our feet. The sunlight coming through the window. The air we breathe. Poets like Conrad Aiken, who wrote the words above, touch some of this strangeness and mystery. And so do scientists. Scientists of the earth–geologists and geographers. Their picture of this small planet, this spaceship earth, is usually couched in more sober words and numbers. But it is no less remarkable and even more awe inspiring.

Let's take a look at the newly emerging scientific picture of our changing earth.

big changes in past and present

The most startling news about earth is how much it has changed in the past and is changing today. Sometimes that change is obvious, fast and spectacular. As when a volcano like Mount St. Helens erupts, spewing millions of tons of ash and dust into the atmosphere. Changing the weather patterns around the globe for months or even years to come.

continents float apart

Other times the change is too slow to notice in a lifetime. These very slow changes are real nonetheless, and even more spectacular in their long-range effects on earth's surface, climate and life. As when whole continents divide and float away from one another. As they have done in the past. And as they are still doing today!

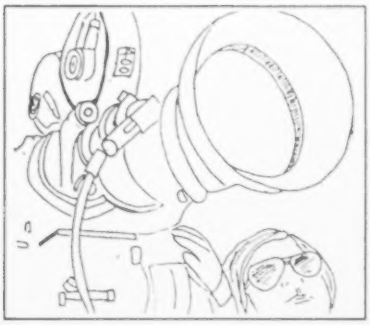
earth five billion years old

To put a change like this into perspective, let's speed it up. The earth we think today is about five billion years old. How earth came to be and to be where it is and how it is, is still unclear. But that it did come to be about ninety-three million

miles away from a medium-sized star, one member of a solar system of eight other planets, is as certain as anything else we know from science.

a time-lapse movie

Imagine that you could watch all the changes of the planet over its five-billion-year history. But watch all these changes speeded up, as in a time-lapse photography movie where you could see the entire history in one twenty-four hour showing. That would mean you would watch over two hundred million years of earth history each hour, over three million years each minute. Here is what you would see.



earth like Venus today

For the first few hours of your viewing, three hundred to five hundred million years in reality, there would be little resemblance to our modern blue-white planet. Earth would look, we think, more like Venus does today. It would be covered with dense clouds made of carbon dioxide, methane, nitrogen, water vapor and sulfuric acid.

molten rock

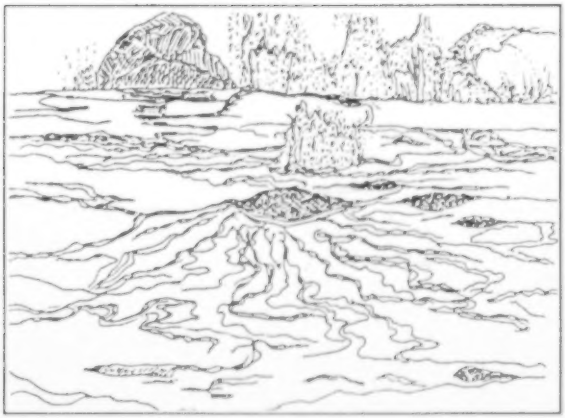
Beneath these dense clouds would be molten rocks too hot for any liquid water to form. There would be no oceans, no rivers, no lakes.

solid land forms

As the hours (millions of years) passed by, that molten rock would slowly cool. On the surface that is. It would stay molten underneath all the way to the end of your twenty-four hour movie. All the way to today.

like an apple crinkling

As earth cools, some parts harden and form solid land. Finally the entire surface forms a hard crust. And this crust crinkles and buckles, like an apple skin does when the apple gets old. And about the same proportion of apple skin to hard apple core.



the rains rain down

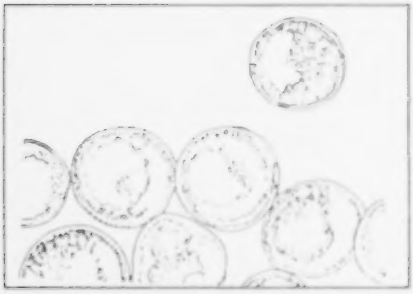
As the crust hardened, the temperature also decreased on the earth's surface, enough for liquid water to condense from hot water vapor. And rains began to fall. And to fall and to fall, for an hour or more of our movie–two hundred million years worth of rain!

the oceans form

Since the surface of the earth was wrinkled and uneven, the rain washed into the low spots and formed what we call oceans.

life begins

If you started the movie at midnight this process would take you from midnight to early morning of your day's viewing. At about dawn (about three billion years ago) you would be privileged to watch the most remarkable event in the history of the solar system, perhaps the history of the Milky Way galaxy. An event that would have profound consequences not only for you as a living being today, but also for the actual surface of planet earth. This momentous event, of course, was the beginning of life in that primeval ocean.



little oxygen

At this point in the earth's history, the atmosphere still had large quantities of carbon dioxide, methane, water vapor, nitrogen and sulfur dioxide. Very little oxygen, however.

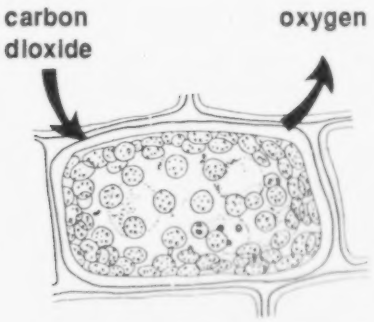
organic soup

These gases dissolved in the rain and ocean waters and formed larger molecules, making a kind of organic soup. Once life came along–that is, even larger molecules and organizations of molecules able to maintain and reproduce themselves–this organic soup provided the food energy needed to stay alive.

And to multiply and to change.

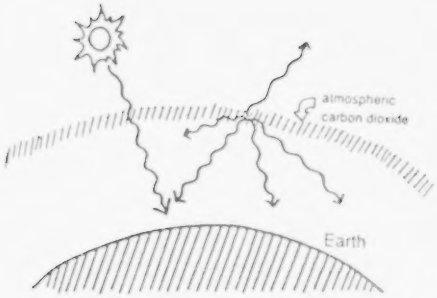
invention of photosynthesis

These life molecules themselves now began to modify and change the earth surface as well. As the original organic soup began to thin, new kinds of life forms developed, forms we today call plants. These first plants, you see, could use the energy from sunlight and the carbon dioxide dissolved in the ocean to make their own food in a process called photosynthesis. In this process of photosynthesis the plants used only the carbon from the carbon dioxide. They threw away the oxygen into the atmosphere.



greenhouse effect

Here is one reason that photosynthesis turned out to be so important for earth. There were fewer clouds and less carbon dioxide. What we today call the "greenhouse effect"–the heating of the earth's surface because of carbon dioxide reflecting solar heat back to the surface–began to lessen. With less greenhouse effect, earth began to cool.



Today we worry about the greenhouse effect warming our climate too much. In those early days the lessening of the greenhouse effect set the stage for a dramatic explosion of life forms not only in the ocean water, but eventually on dry land as well.

the continents 500 million years ago

In those early years of life we don't know exactly what the surface of the earth looked like, though we know it was very different from today. The most compelling recent evidence from magnetic rock samples leads us to believe a map of the world would have looked very different five hundred million years ago. Most of the land would be clumped together in one giant continent in the Southern Hemisphere. A world rock island in a sea of ocean life. All, remember, still floating on a deeper sea of molten rock. This one continent was called Pangaea by the scientist who discovered it.

life begins as continents break apart

Sometime around the time life forms began creeping out onto the land, about four hundred million years ago–ten o'clock in the evening in our speeded up movie–Pangaea began to split apart. And the resulting pieces–what we call continents

today–began to slowly float away from each other. Slowly. Very slowly the surface of the earth took on a different pattern.

earthquakes and volcanoes

During all this time, and right on up to today, the movement of these continental plates would cause periodic earthquakes and volcanos. The molten rock would often break through some of the cracks in spectacular eruptions.

life on land

As the rock shifted, and as the ocean floor rose and fell, jagged mountain peaks were formed. Also deep ocean basins, shallow flat plains and swamps and bogs and deserts and forests. For by three hundred million years ago life had invaded all parts of the land surface.

fossil fuels made

The huge swampy forests of that day made what we call coal, oil and gas today. That day was called the Carboniferous Age of earth.

mountain-building and erosion

As fast–or rather as slow–as the mountain ranges formed they began to erode away. Rain, wind, ice and snow gradually brought even the highest mountain peaks down to the valley floor. And that valley floor got heavier. When it got too heavy it sank into the molten rock below and became the basin of an ocean. Which in turn pushed under the continents raising the plains back up into mountains again.

still going on today

All of these same slow powerful processes are still going on today. Occasionally, as in the volcanic eruption of Mount St. Helens, or in a violent earthquake, we are abruptly made aware of the power beneath our feet. And of the plastic, fluid, changeable surface we call home.

tectonic plates

Here is a map of the present position of these tectonic plates. Notice that one of the few places where a large fissure comes through a land area is in Iceland. And in Iceland today you can actually visit and stand upon a continental crack.

fire department cools a volcano

And in Iceland today you can see all over the island places where the steam and the lava are continually breaking through the fragile thin surface rock layers. Sometimes they break through explosively, as in 1975 when the entire city of Haemey was threatened and partially engulfed in the lava from a volcanic eruption. The fire department actually pumped water from the ocean to cool the lava and so save much of the town.

geothermal energy

Most of the time the steam and heat comes through steadily and peacefully. Engineers in Iceland can control this steam and heat so that all the nation's factories, houses, greenhouses and swimming pools are kept warm by it, and much of the electricity is made by it.

fire and ice

Besides fire and heat and steam and explosions, the other extreme of ice and snow has played an

equally large part in forming our present landscape. We know now that many times over the past few million years, the earth has gone through periodic colder cycles. During these cold times the average temperature declined only a few degrees, but this was enough to allow the northern ice packs to grow. As they grew they moved south and covered much of the northern part of the northern hemisphere time after time.

most recent ice age

The most recent ice age began about two million years ago and has not ended yet. During these past two million years the ice has moved down in giant glaciers to cover northern North America and northern Europe with mile-thick ice at least five times. Each time it then retreated in warmer inter-glacial periods. Each advance and retreat changed the face of the land dramatically.

what glaciers do

The ice gouged out large glacial valleys. It pushed sand and gravel in front of it to form rounded drumlin hills. It cut deep and shallow basins in the bed rock which later filled with melted glacial water to form the Great Lakes and the thousands of smaller lakes in Minnesota, Michigan and Wisconsin. Today we live in a warmer inter-glacial

period. But most geologists and climatologists expect the ice to return within the next five to ten thousand years. Less than one second on our one day viewing movie!

the big picture

So that is the big picture. How fire and ice–and life–have shaped our planet. Of course we have left out a great many details.

minerals and ores

How beautiful minerals, for instance–diamonds, rubies, sapphires and opals–were formed in crevices of ancient rocks. How useful metallic ores like hematite, taconite, copper and zinc oxide were also formed by geological processes deep in the earth's crust.

kinds of rocks

How sedimentary, metamorphic and igneous rocks have formed and pressed against one another, invaded one another and been layered into one another. How fossils of billions of living creatures of the past have been buried and preserved in some of these sedimentary layered rocks.

changes due to human actions

And most important of all, we have only been able to hint at the most remarkable of all changes, those brought on by human beings. For in that final minute of our movie–the three-million-year time that *Homo sapiens* has been around, you get some of the fastest changes of all.

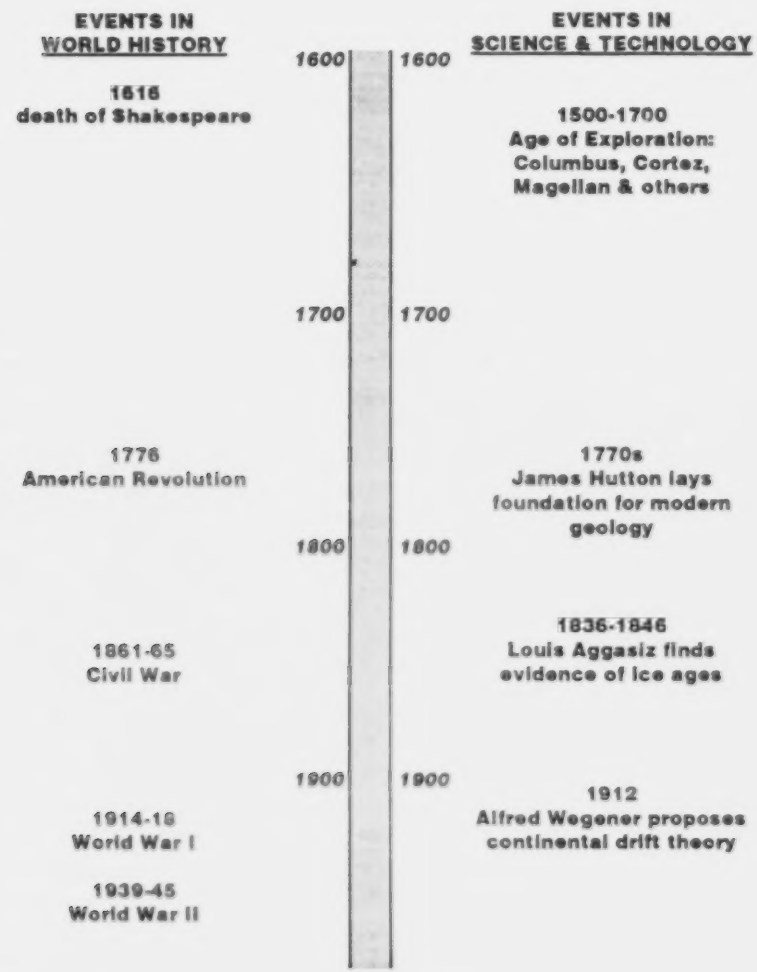
making earth more human

Agriculture, mining, forestry, manufacturing, politics, economics, philosophy and religion. All these have radically changed the surface of the earth and are still doing so. Making it more human here, more barren there. Making it all the more interesting for the human geologists and geographers among us.

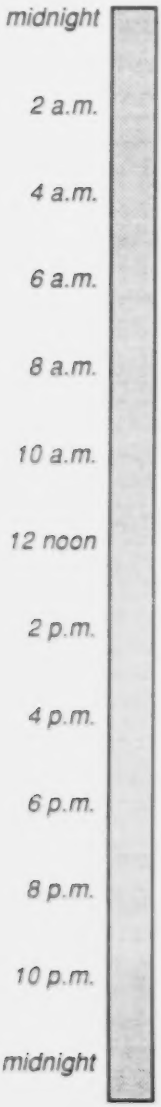
What happens to spaceship earth–and to its passengers and crew–in the next second of our movie will to a large extent be up to you and me.

TIME ...

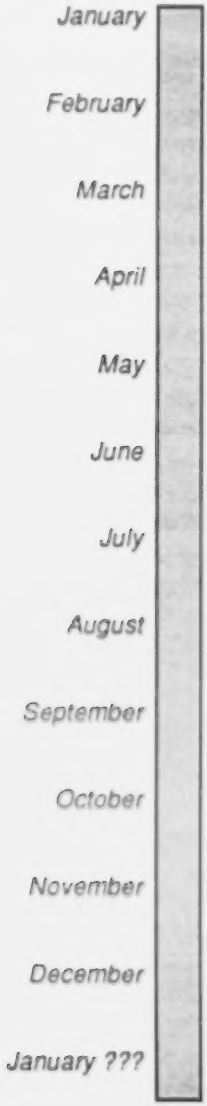
To understand the world of today it helps to know something about the world of yesterday. Kings and queens, wars and famines, presidents and paupers have all played a part. But more important than any of these in changing the past world into the world of today has been science and technology. The time line below will help you place important events and people in historical time.



The time line below summarizes 4.3 billion years of earth history. Imagine you are making a time-lapse movie in which each minute of your movie shows three million years of life on earth. On this scale two hundred million years go by every hour. The entire movie will take one twenty-four-hour day to show. It begins at midnight.

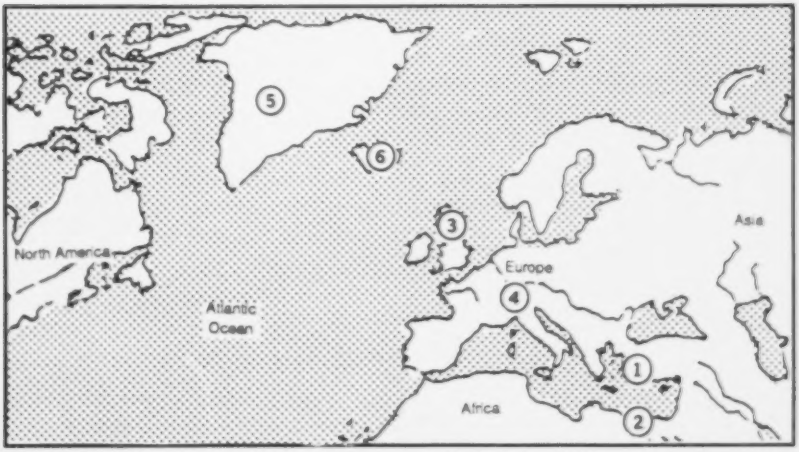


The time line below summarizes 730 million years of earth history. Imagine you are making a time-lapse movie in which each second of your movie shows twenty-four years of life on earth. On this scale 1,440 years go by every minute, 86,400 years an hour, two million years a day. The entire movie will take one year to show. It begins January 1.



SPACE ...

There is a saying, "If you don't know where you are going, any road will get you there." One of the important parts of knowing where you are going is a knowledge of geography. The map below will help you to locate the important events and people discussed in this book.



1. Ionian Greece — Where world's first scientist/philosphers lived and worked. Now a part of modern Turkey.

2. Alexandria, Egypt — Where the Greek astronomer and geographer, Ptolemy, drew his famous maps and put together an atlas that was the world standard for over a thousand years.

3. Scotland — The highlands of Scotland where James Hutton founded the modern science of geology in the late eighteenth century.

4. Switzerland — Where Louis Aggasiz first found evidence of continental glaciers and ice ages.

5. Greenland — Where the German geologist and astronomer, Alfred Wegener, worked and found evidence to support his theory of continental drift.

6. Iceland — Much evidence of geothermal energy where the tectonic plates collide under land surfaces.

SPIRIT...

Time and space are meaningless without spirit. Spirit is the part in each of us that understands. The part that sees connections between words and things–connections that surprise and make sense. Study the key words, concepts and ideas below so that you can understand how time, space and spirit have worked in the past–and are working today.

Agassiz, Louis — A scientist of the nineteenth century who first proposed the modern theory of continental glaciation. (p. 8-9)

atlas — A book of maps. (p. 3, 5-6)

biosphere — The very thin outermost layer of planet Earth where life flourishes.

carbon dioxide — A compound whose molecule has two atoms of oxygen to one atom of carbon. (p. 14, 16-17)

Carboniferous Age — The age of earth history approximately three hundred million years ago when oil, coal and natural gas were formed from the decay of ancient plants and animals. (p. 18)

continental drift — A theory proposed by Alfred Wegener that claims the continents float on top of underlying molten rock. Today it is usually called the theory of tectonic plates. (p. 10-11, 17-19)

ecosystem — Living things and the environment in which they live considered together as a single system.

erosion — A wearing away of surface rocks and soil by the action of water, wind or ice. (p. 18)

fossil — Imprints or remains of plants or animals of the past preserved in rock. (p. 6-7, 9, 21)

galaxy — A large group of stars that move together in the universe. Our solar system is a part of the Milky Way galaxy, one of billions of such galaxies in the known universe. (p. 15)

geography The science that studies the surface of the earth and the activities of human beings on that surface. (p. 1, 5-6, 12, 21)

geology The science of the changing earth. See this book.

glacier Large masses of snow and ice that do not melt in a single season. At one time continental glaciers covered most of northern North America, Europe and Asia. (p. 8-9, 19-20)

greenhouse effect A gradual warming of earth's climate caused by excessive carbon dioxide which reflects heat back to earth instead of letting it escape into space. (p. 16-17)

Hutton, James A Scotch scientist (1726-1797) who is credited with founding the science of geology. (p. 1, 7-8)

ice age There have been many ice ages in earth's past. The most recent ice age ended about ten thousand years ago. (p. 8-9, 20-21)

igneous rocks Rocks created by great heat in the earth. (p. 7, 21)

metamorphic rocks Rocks that have been changed by heat and pressure. (p. 7, 21)

mineral A naturally occuring chemical with a definite composition and crystal shape. Combinations of minerals make up rocks. (p. 21)

ores Minerals that contain significant amounts of desirable metals or other industrial chemicals. (p. 21)

oxygen An elemental gas very important for life and a major part of our atmosphere. (p. 16)

photosynthesis The process in which green plants make food using carbon dioxide and water, and the energy of sunlight. (p. 16)

Ptolemy An early Greek astronomer and geographer who lived and worked in Alexandria, Egypt in the second century A.D. Prepared maps and an atlas that was the world standard for over a thousand years. (p. 3)

sedimentary rocks — Rocks created by water depositing minerals in layers over long periods of time. (p. 7, 21)

solar system — The system of planets, comets, asteroids and other celestial objects revolving around our sun. There may be solar systems around other suns in the galaxy. (p. 13-14)

spaceship earth — A term applied to our planet in the space age. (p. 12, 21)

tectonic plates — Modern form of the continental drift theory of Alfred Wegener. The surface of the earth is divided into several huge masses of rock about thirty miles thick. The continents ride on top of these giant tectonic plates, which float on top of underlying molten rock. (p. 10-11, 13, 19)

Wegener, Alfred — A German geologist who first proposed the theory of plate tectonics. (p. 10)

In addition to the above, *The Changing Earth* also teaches about other important people, places, things and ideas. Often you can figure out the meaning of a new term by seeing how it is used in context. Make sure you know the meaning of the following (for help, check the pages listed in this Learning Power Book, as well as your dictionary and encyclopedia):

Aiken, Conrad (p. 12); **Anaximander** (p. 4); **British Isles** (p. 3); **Buffon, Georges** (p. 6); **China** (p. 3); **drumlin** (p. 9); **earthquakes** (p. 11, 18); **Egypt** (p. 2-3); **geothermal energy** (p. 19); **Great Lakes** (p. 20); **Greece** (p. 2); **Homo sapiens** (p. 21); **Iceland** (p. 11, 19); **India** (p. 3); **Ionian Greece** (p. 3-4); **Mediterranean Sea** (p. 1-2); **Middle Ages** (p. 3, 5); **Mount St. Helens** (p. 13, 18); **North America** (p. 3, 8, 20); **Pangaea** (p. 10, 17); **Phoenicia** (p. 2); **Renaissance** (p. 3, 5); **Scotland** (p. 1, 7); **Southern Hemisphere** (p. 17); **Switzerland** (p. 8); **Thales** (p. 4); **Venus** (p. 14); **volcanoes** (p. 11, 13, 18-19).

STUDY SUGGESTIONS ...

1. Considering the importance of his contribution, James Hutton is not a well known figure in the history of science. Read the book by John Harrington (see bibliography) for exciting insights into Hutton and his work. Harrington also has good descriptions of the work of other nineteenth century pioneers in geology.

2. To better appreciate the evolution of map-making, make some free-hand maps of your city, state, country and world. Compare your maps with those in a standard atlas. Note and discuss the differences.

3. This book uses a time-lapse movie analogy to help appreciate the long time spans involved in earth history. Make up some other analogies and construct time line charts for the same history. Change the scale to include only the earth history since life emerged from the ancient oceans. Since the dinosaurs ruled the earth. Since primates appeared. Since the last ice age. Since civilization began.

4. Many people believe that human activities, especially industrial and urban ones, have always and everywhere degraded the natural environment. For a vigorous dissenting view, see the book The *Wooing of Earth* by Rene Dubos.

5. Rock collecting and fossil collecting are fascinating and popular hobbies. They are also the way many earth scientists got started. Begin your own rock, mineral and fossil collection. *The Audubon Society Guide to North American Rocks and Minerals* (see bibliography) will help you get started.

6. Iceland is not the only place where geothermal energy is available for human needs. In fact, almost everywhere on earth simple heat pumps can provide a way to take advantage of earth's heat. Investigate the potential of heat pumps in your own community.

7. A fascinating and relatively unexplored field is tracing the influence of ideas on the physical structure of our changing earth. How, for instance, has the idea of democracy, of human rights, of Marxism, or free markets changed the face of the earth? For better, or for worse?

8. Investigate using current periodicals the changes on earth today due to acid rain, greenhhouse effect, toxic wastes, or ozone depletion.

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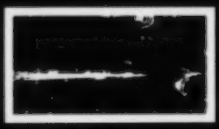

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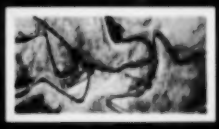

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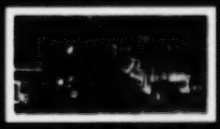

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